The Making of

ROCKETS.

In Two Parts.

The First

Containing the Making of *Rockets* for the meaneſt Capacity.

The other

To make *Rockets* by a Duplicate Propoſition, to 1000 pound Weight or higher.

Experimentally and Mathematically Demonſtrated, By

ROBERT ANDERSON.

LONDON:

Printed for *Robert Morden*, at the *Atlas* in *Cornhil.* 1696.

To the Right Honourable

HENRY

Earl of *Romney*.

Vicount Sidney *of* Sheppy, *Baron of* Milton, *Maſter General of his Majeſty's Ordnance, Conſtable of* Dover *Caſtle, Lord Warden of the Cinque Ports, and one of the Lords of his Majeſty's moſt Honourable Privy Council.*

WELL knowing my moſt Noble Lord, that theſe things will eaſily receive Perfection in your Hands, which for many Reaſons are beyond my reach.

This Treatiſe (if it may deſerve that name) is the leaſt in

Bulk, and ſeemingly relating to the ſleighteſt Subject I have met withal in *Pyrotechnia*. But in the many Volumns great and ſmall that I have read relating to theſe Matters in our own and other Languages; I do not find the leaſt Pretence or Thought of doing *that* which here is undertaken, *viz. To raiſe ſo great a heap of Fire, and to confirm the Fact by the greateſt Proofs that can be had or wiſh'd for, which are Experiments and Demonſtrations Mathematical.* Yet this alone is not the matter aim'd at, the Problem is univerſal, and applicable to the Fortifications of all ſorts of Guns and other Engines with their Carriages, *&c.* and is *to increaſe or decreaſe the ſtrength of Materials according to the Effects and Services required.* But the greateſt Skill in this Undertaking being to

to adjuſt the Inſtrument and Means in a due and proper Proportion to the Effect ſought for; I do with all Humility and profound Reſpect make offer of this ſmall Eſſay.

It is your Lordſhips great Abilities and Merit, that has enabled you to tread the intricate and painful ſteps of Greatneſs; and by the well diſcharging ſo many Eminent Employments, to add, (if any thing can be added) to the Great Name of your Renowned Anceſtors. An ardent Zeal for the Welfare and Honour of your Country, has always been the inbred Vertue of your Family, and which is brought to its Perfection in your ſelf.

The Name of *Maſter General* of the *Ordnance*, lays Claim to all my (more than 25 Years) Ex-

 perience

perience and Studies about the Art of Shooting in all ſorts of Great Artillery amounts to: But the adding ſomething (according to my poor Sphere and Capacity) to the Defence, Safety and Reputation of my Native Country, has at all times ſo intirely govern'd me, that upon this account alſo, and indeed chiefly, I am emboldned to lay this mean Attempt of mine before your Lordſhip; truſting that it may at ſome time or other undergo a Trial, and by your Lordſhips Favour receive a meet Incouragement, and procure your Lordſhips Pardon, &c. to

My Lord,

Your Lordſhips moſt Obedient,

Humble Servant,

Robert Anderſon.

TO THE

Young PYROBOLISTES.

ROckets are the moſt Artificial piece of Fire-work yet uſed amongſt the Pyroboliſtes, and hath been more uſed of late Years than formerly, and that the Young Artiſts may not ſpend their Time and Money unneceſſarily, I have given eaſie, plain, and ready Rules for making of Rockets to two Inches and half Diameter, which is ſufficient for all private Occaſion, viz. *Of the Mould of a Rocket. Of the Rouler and Caſe. Of the Compoſitions. Of the Receipts of Rockets. Of the Driver. Of the Boring of the Rocket. Of the Stars and other Matter to be put in the Head of a Rocket. To Head a Rocket. Of the Sticking of a Rocket. And laſtly, to Fire the Rocket. And ſome Obſervations about the manage-*

ment of a Rocket in general; all which I hope will prove caſie and beneficial to the Ingenious, and thoſe that are willing to Learn: and what you do, endeavour to do it well, and do not be Conceited; which if ſo, I have my ends. And from theſe little beginnings greater Matters may be obtained, and you may become ſerviceable to your Country; in which be ſure to be Careful, Honeſt and Faithful.

TO

TO THE

Other PYROBOLISTES.

ABout fifteen Years ſince I conſidered of a method to increaſe or decreaſe the ſtrength of the Metal of Guns, which is this that I intend to diſcourſe of. And at the Cloſe of a ſmall Treatiſe to hit a Mark publiſhed in the Year 1691. *I propoſed that Problem in Print; ſince that time there has been more than Ordinary occaſion for it, by Reaſon of the new Caſting of the Mortar-pieces. About two Years ſince I put that Problem into a method, and made a Draught of the whole matter to increaſe or decreaſe the ſtrength of the Metal of a Gun in any poſſible Proportion aſſigned. But when I ſaw the Mortar-pieces brought from Sea broke, it was thought to be a good time to ſhew it, which*

which was done, and the whole matter diſcourſed of at large, but it ſignified 00. *But now I apply that Problem to the making of Rockets for the young Artiſt, as you ſee in its proper place. And it is manifeſt that the young Rocket-makers of this City are very Careful and Artificial in their Rockets of* 8 d. 12 d. *or* 18 d. *value, otherwiſe they may break and ſo loſe their Labour and Diſcredit themſelves. Seeing theſe Mathematical Rules are ſo applicable to the greateſt nicety of the Riſing of all ſizes of Rockets; is it not more valuable to be applied to thoſe Chargeable Inſtruments of War,* viz. *Guns of all ſorts, with their Carriages, and all other their Furniture?*

As to the Doctrine of ſhooting by the increaſe and decreaſe of Powder, this way of making of Rockets proves it to be abſurd; for all Rocket makers to this time weaken the Compoſition of their Rockets, as their Rockets are in greatneſs, or having greater quantities of Compoſi-

Compoſition; and that by chance, and without any Mathematical Demonſtration.

And alſo by Experience, in Table June 1. 1691. *and in the firſt Column Experiment* 4, *againſt that in Column* 2 *you will find* 4 *Ounces of Powder, and in Column* 3, 3377. *Again, in Column* 1, *againſt Experiment* 1 *in Column* 2, *you find* ½ *an Ounce of Powder, and againſt that in Column* 3, *you find* 213; *now becauſe the Requiſite of Powder are as* 8 *to* 1, *therefore I multiply* 213 *by* 8, *and it makes* 1704, *much ſhort of* 3377, *which indeed ſhould have been equal to the ſaid* 3377. *that is the Ranges upon the plain of the Horizon are not as the Requiſites of Powder which projected thoſe Ranges; the like may be done in all the other Experiments. I have made hundreds of Experiments in ſeveral ſorts of Mortar-pieces, and am ready to make as many more, all which will manifeſtly confute the Doctrine of ſhooting by the increaſe and decreaſe of*

of Powder, and have often invited the firſt promoter of that Doctrine to ſee his Invention confuted; and I do here invite all the Practitioners in that Science of ſhooting by the increaſe and decreaſe of Powder, to come and ſee their Doctrine confuted. I do hear aſſert it is impoſſible ever to bring that way of ſhooting to be ſo exact and ready for uſe, in all or any ſorts of Guns, as the common or uſual way is, by keeping the Requiſites of Powder conſtant, and elevating the Piece. In the Complicating of Rockets, whoſe Diameters are at any great diſtance; we make uſe of Experiments of ſhooting made upon another Occaſion, and thoſe Experiments ſerves ſufficiently well; but if we were to do them juſtly according to Art, there ſhould be two even Chaſed Guns of the ſame Proportion as the Rockets are of, that is the Diameter of the expoſed Rocket 2 ½ Inch multiplied by 6 is 15 Inches, and thoſe ſhould be the Diameter and length of one of the Guns: 4 Inches the Diameter of the other Rocket, multiplied by 6 is 24 Inches, which 4 Inches for the

the Diameter, and 24 Inches for the length ſhould be the other Gun, or any two Guns in that Proportion. For the Requiſite of Powder take the Cube of 4, which is 64, as alſo the Cube of 2 ½, which is 15.625, divide the greater Cube Number by the leſſer, and the Quotient is 4, ſufficiently near; ſo the Requiſites of Powder of theſe two Pieces are as 4 to 1, then take any reaſonable Requiſite of Powder for the 4 Inch Gun, then take the fourth part of that Requiſite for the Requiſite of Powder for the leſſer Gun, diſcharge them both at one degree of Elevation, and note their Ranges. Their Bullets are to be of the ſame Metal, and of the ſame likeneſs, and both exactly fit. In a Mathematical ſence theſe Ranges ſhould be equal; but by Combination the greater quantity of Powder aggitates more upon the great Bullet, than the leſſer Requiſites doth aggitate upon the leſſer Bullet, and that cauſes thoſe differences, the like when two quantities of Powder aggitate upon one Bullet; it is Experience only that deter-

determines the matter. Although ſtrange things ſometimes happens; yet this we will Aſſert, and endeavour to maintain that Mathematical Knowledg, join'd with faithful Experiments, will do greater matters than moſt Men commonly conceive.

Rob. Anderſon.

Rocket Moulds are made by Mr. *Cuggley* juſt without *Cripplegate.*

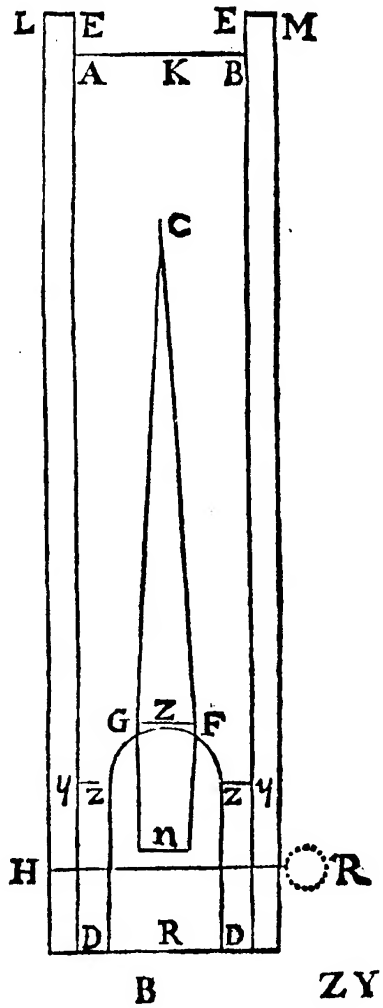
Taper Bits for Rockets, are made by Mr. *Goode* juſt within *Cripplegate.*

Rods for Rockets, are made by Mr. *Stateham* in *Token-Houſe-Yard, Lothbury.* All three right good Workmen.

PROPOSITION I.

Of a Rocket-Mould.

LEt EMR LDDHLE be a Rocket-Mould, A B the Diameter of it, *viz.* one Inch and half; Z K 4 Diameters; that is 6 Inches the height to be filled with Compoſition, B E half a Diameter an overplus, Z C the height of the boring 4 Inches and $\frac{1}{2}$, or $\frac{3}{4}$ of the height of the Mould, G F the Orifice one third of the Diameter of the Rocket half an Inch,



ZY one ſixth of the Diameter of the Rocket a quarter of an Inch, the thickneſs of the Caſe, DYZGCFZYD the bottom of the Rocket-Mould with the Needle to be put in and taken out; RH a Pin of Iron to fix the Mould and Bottom together.

PROPOSITION. II.

Of the Rowler and Caſe of a Rocket.

MAke the Body of the Rowler nine Diameters in length, and in Diameter two thirds of the Diameter of the Rocket, and the Head of the Rowler of the Rocket the ſame Diameter; let the Diameter of the Neck of the Rowler be a little leſs than one third of the Diameter of the Rocket, becauſe when opened with a Cone of Wood the Orifice of the Rocket may be juſt one third ſmooth and hard to endure the Fire. Then the thickneſs of the Caſe will be one ſixth of the Diameter of the Rocket, which being well Rowled and Choaked, the Caſe may be finiſhed.

(3.) *Of*

PROPOSITION III.

Of the Compoſition for Rockets.

THE Ingredients which Rockets are Compoſed of are Saltpetre, Sulphur, and Wood-Coal mealed, and paſſed through a fine Sieve. Firſt, take the largeſt of Small-Coal made of Birch-Wood. Secondly, chuſe the Yelloweſt Roch Sulphur. Thirdly, take Saltpetre put in a Braſs Veſſel, to which put ſo much fair Water as will diſſolve it, put that Veſſel upon the Fire, when it boils ſcum it clean; when the Water evaporates and conſumes, ſtir it with a Spatula of Wood to meal it, what remains of the Saltpetre upon the Spatula, and ſides of the Veſſel, rub off with your Spatula of Wood; then meal it, and paſs it through a fine Sieve. A ſecond way to Clarifie Saltpetre; take a Crucible, ſet it in the Fire, put Saltpetre thereunto, increaſe the Fire till the Saltpetre be Reduced to a liquid quality like Water; when it boils take mealed Sulphur upon a Spatula of Iron, and put it into the boiling Saltpetre; ſo often repeated, the Flegmy quality of

the Saltpetre will be burnt away, and the flame will remain as white as the Body of the Sun. Then pour it into ſome very ſmooth Veſſel, which being cooled, you may reduce it into meal. Theſe ways I have done for my Recreation; but I uſually take the cleaneſt Saltpetre to be found in Drugſters Shops, and it does as well.

PROPOSITION IV.

The Receipts for Rockets.

FOR an Inch, an Inch and half, and two Inch Rocket, and for a White Fire, take 2 Drams of Antimony, 1 Ounce of Sulphur 2 ½ Ounces of Coal-duſt, 6 Ounces of Saltpetre, and 8 Ounces of powder duſt, [*Caſimer du Grand Art d' Artillerie, Partie* 1. *Livre* 3. *pag.*145.] Fill 4 Diameters and Bore 2 ½. For an Inch and half, and two Inch, and two Inch and half Rocket, and a Yellow Fire, take 1 Ounce of Sulphur, 1 Ounce of Coal-duſt, 4 Ounces of Saltpetre; or take 1 Ounce of Sulphur, 1 ½ Ounce of Coal-duſt, and 4 Ounces of Saltpetre. [*Caſimer du Grand Art d' Artillerie, Partie* 1. *Livre* 2. *pag.* 99.] Fill 4 Diameters, and bore 3, or a little more

more. And *Daniel Elrich Der groſſen Kunſt Artillerie Zweiter, Theil. pag.* 54. *art.*19. Adviſes to take 1 Ounce of Sulphur, one Ounce of Coal duſt, 4 Ounces of Saltpetre. Again, take 1 Ounce of Sulphur, 2 Ounces of Coal, and 6 Ounces of Saltpetre; alſo take 1 Ounce of Sulphur 2 ½ of Coal, and 6 of Saltpetre. *Johann. Sigmund. Buchner in Theoria & praxis Artilleria Andere Theil, pag.*28. Weigh the Ingredients ſingle, put them into a wooden Bowl, mix them very well together, and paſs them through the Sieve, then your Compoſition is fit for uſe. In filling Rockets of one or two Inches Diameter; let them be filled at 6, 8, or 10 times Charging, and to every Charge 10, 12, or 14 blows with a Mallet, and betwixt every three blows turn the Driver a little in your Hand, ſo the Compoſition about the Needle will be preſerved.

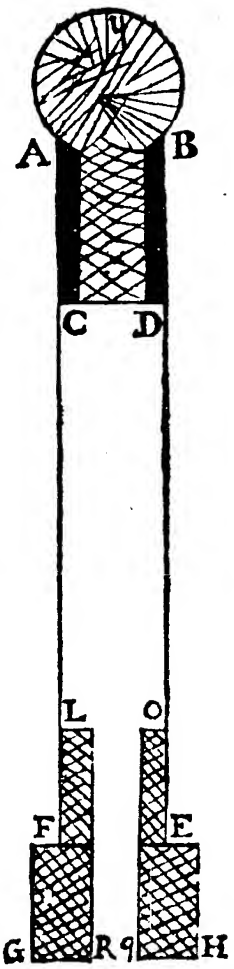
Some of our Rocket-Makers cry up the Compoſitions of *Woolverman* and *Nelſon*, as though there was no Compoſition to be found like theirs, and they are thus: that falſly called *Woolverman's* is 1 of Sulphur, 1 of Coal, and 4 of Saltpetre: and that of *Nelſon*, 1 of Sulphur, 1 ½ of Coal, and 4 of Saltpetre, as they ſtand in the Remains of

Mr. *Francis Deane*, ſometime Gunner of the *Tower*. Theſe Compoſitions are Old and Common, as you ſee, they are Good, Strong, and dull Compoſitions, and eaſily mannaged. Thoſe Compoſitions where Powder is judiciouſly mixed are more lively, and ſo more difficult to mannage.

PRO-

PROPOSITION V.

Of the Driver of a Rocket.



LEt yAFGHEBy be the Driver of the Rocket, A F E B a piece of a Gun Barrel, F G H E O L a piece of Box or hard Wood, R L O q a hole for the Needle to paſs through, A C D B y a piece of Box to drive upon; this we call a hollow Driver, it diſpatches buſineſs quickly, and does right well. Or you may faſten a piece of Braſs in the end of your Iron Driver with a hole in it to receive the Needle.

If any will uſe a ſolid Driver, let them have the bottom of the Mould as D y Z Z Z y D with a hole paſſing through the bottom, as Z R, for a ſtrait Piercer to paſs through

which bottom will be a Guide to the Piercer to be juſt in the middle of the Rocket, make a mark in your Piercer to be a guide to bore always an equal depth, then take your Rocket out of the Mould, open the hole with a Taper bit, and your Work is done, thus you may do for all ſizes of Rockets.

PROPOSITION VI.

Of the Boring of a Rocket.

MAke the Diameter of your Borer one third of the Diameter of your Rocket, not for any neceſſity, but for conformity to the other parts of the Rocket; from that Diameter let it be exactly Taper to a point. Further, there being an entrance made by the Needle, it is very eaſie to bore the Rocket very exactly, by holding the Rocket in the Left Hand, and the Borer in the Right, moving the Rocket in the Left Hand, keeping the Borer faſt in the Right Hand.

If you make the Diameter of the Needle one third of the Diameter of the Rocket, and ſo Taper, you need no Borer;

Borer; here you ſhall find the Rocket will riſe ſwifter than when bored, the Compoſition lying looſer about the Needle than if it were bored, takes fire eaſier, and this is moſt neceſſary in large Rockets, *viz.* of 3, 4, or 6 Inches Diameter; for ſuch will hang too long time upon the Nails before they riſe. Thoſe Rockets whoſe Compoſitions are Compoſed of mealed Powder, Saltpetre, Coal and Sulphur, fill four Diameters, bore two and half. Thoſe Compoſed of Saltpetre, Coal, and Sulphur fill four Diameters, bore three or a little more.

This will hold in Rockets of 1 Inch, 1 ½ and 2 Inches, but in larger Rockets there muſt be leſs ſolidity to the hollow Cone of Fire. I uſed for many years to drive my Rockets ſolid, and to bore them after, but that way did no better than theſe I now uſe and deliver; but this is moſt certain that any one may drive and bore 3 Rockets with thoſe hollow Drivers which I now uſe, whilſt one many finiſh the driving and boring of one Rocket with a ſolid Driver; when the Rocket is near filled, uſe a ſhorter Driver with a ſmaller hole.

PROPOSITION VII.

Of Stars for Rockets.

1, 1, 2, 2. Sulphur.
2, 3, 3, 2. Antimony.
4, 6, 8, 6. Saltpetre.

Meal theſe Ingredients fine, paſs them through a Sieve, mix them with Water in which ſome Glue, or Gum Araback, or Gum Dragon hath been diſſolved, make them of the bigneſs of a Hazle Nut, or ſmall Wallnut; roul them in meal Powder, when dryed they are fit for uſe.

Rockets are headed with ſmall Serpents, their Orifices waſhed with mealed Powder and Brandy Wine, to take Fire.

Of

Of Rain and Hail.

TAke any of thoſe Receipts for Stars, *viz.* 1 Sulphur, 2 Antimony, and 4 Saltpetre; if you moiſten that Compoſition with Oil of Petre only made well into Paſte, formed into little Globes, rowled into mealed Powder; ſuch Stars will have Red Colour: the ſame Compoſition moiſtned with Linſeed Oil will have a Red mixed with White: the ſame Compoſition mixed with Oil of Petre and Linſeed Oil mixed together, will make an Amethiſt Fire. All theſe will require a long time a drying, the beſt time is to make them in the Summer.

The ſame Compoſition mixed with Gum Araback Water, and Colophone, gives a Red Yellowiſh Fire. The former Compoſition moiſtned with Brandy and Oil of Petre, or Linſeed Oil, mixed together, requires leſs drying. Powder of Glaſs, Powder made of Sawduſt mixed with the former Compoſition gives different Fire; Coal duſt inſtead of Antimony, all which you may govern by your own Reaſon. Take the Old Proverb, *So many Men, ſo many Minds.*

(8.) To

PROPOSITION VIII.

To Head a Rocket.

TUrn a piece of Wood juſt ſo big as your Rocket is, with a Cone at one end thereof, paſte a piece of ſtrong Paper about the Wood, then paſte another piece of Paper about the Cone, and paſte both Papers together; then put your Stars into this Paper Veſſel, with ſome Rocket Compoſition to break the Veſſel, then put a little Paſte a little within the ſides of this Paper Veſſel, then draw it upon your Rocket, and paſte it to the Rocket, ſo your Work is done.

PROPOSITION IX.

Of the Sticking of Rockets.

THE Stick of a Rocket ought to be ſeven times the length of the Rocket or more, *viz.* a Rocket of an Inch and half, ſix Diameters thereof, the length of the Rocket, is nine Inches, ſeven times

times nine is ſixty three Inches, that is five Foot three Inches. The breadth of the Stick at the Head, three quarters of an Inch or leſs, the thickneſs half an Inch or leſs, the ſmall end of the Stick three eighths of an Inch and ſquare, and to be made of light Deal; ſuch a Stick will do very well, and may be counted Cuſtom without Demonſtration. In the Winter 1695. there were two ſets of Fire-works, in the firſt of which the Wind was Northward, and the Rockets in their riſing worked into the Wind. In the ſecond the Wind was Weſtward, and had the ſame effect as the firſt; the Reaſon was becauſe the Stick was to heavy at the upper end, and too light at the lower; and ſo the Center of Gravity of the Rocket and Stick was too near the Rocket: when indeed the Center of Gravity ſhould be in the middle, betwixt the lower end of the Stick and upper end of the Rocket; and to do which the bigger end of the Stick ought to be downward; by this means a lighter Stick would ſerve, and if the Wind did drive the Rocket, the Rocket would move leſs, and yet perpendicular to the Horizon. Nature it ſelf has taught us the ſame; for all Birds, eſpecially Birds of a ſwift flight, ſpread their Tails for their Guide. Sticks of Rockets ought to be one

to

to another as the length and Diameters of the reſpective Rockets; that is, as the Diametre 1 ½ Inch is to the thickneſs of its Stick, ſo is 4 Inches the Diameter of a 4 Inch Rocket to the thickneſs of its reſpective Stick. As the length of one Rocket is to its Stick; ſo is the length of any other Rocket to its Stick: and as the weight of one Rocket is to the weight of its Stick; ſo is the weight of any other Rocket to the weight of its reſpective Stick.

PROPOSITION X.

To fire the Rocket.

PLace the Rocket perpendicular to the Horizon by four Nails, make a port-fire, about half an Inch in Diameter, with ſingle Paper, *viz.* 1 Sulphur, 2 Saw-duſt ſifted fine, or rather Logwood beaten and ſifted fine, 4 of mealed Powder, and 8 of Saltpetre; or make the port-fire with Rocket Compoſition: fire the port-fire, move it gently towards the Orifice of the Rocket till it takes fire.

Obſer-

Obſervations concerning Rockets.

(1.) IF a Rocket be driven not hard enough it either conſumes or breaks; if juſt hard enough it riſes well; if two hard it turns a loft, and breaks not at the juſt turn.

(2.) If a Rocket be bored not deep enough it will not riſe well; if juſt deep enough it riſes well; if too deep it often breaks.

(3.) If a Rocket be bored with too great a Borer it will not riſe well; if with a fit Borer it riſes well; if with too ſmall a Borer it breaks, or riſes not well.

(4.) If the Compoſition be too moiſt it will not riſe well; if too dry it riſes too faſt or breaks.

(5.) If a Rocket be made, and kept in too dry or too moiſt a place, it will have the ſame effect as at the (4.)

(6.) The

(6.) The Velocity of a Rocket is cauſed by the boring, or in the hollow Cone; the time of its flight is in the ſolid part above the boring, which ſolid part ought to be leſs in a great Rocket than in a little one. From theſe Obſervations a Youth may take any Compoſition (in Reaſon) and make a good Rocket.

PROPOSITION XI.

The weight of the Mallets for Rockets.

THE weight of the Mallets which Rockets are driven with, ought to be as the Cube of the Reſpective Diameters of their bores, *viz.* If the weight of the Mallet for an Inch Rocket be twelve Ounces, the weight of the Mallet for an Inch and half Rocket ought to be two Pounds and half, and for a two Inch Rocket ſix Pounds, *&c.*

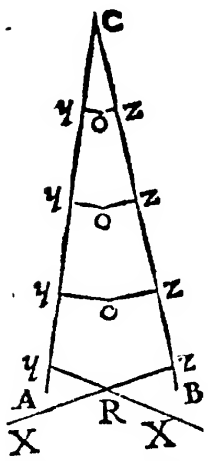
PROPOSITION. XII.

How Rockets are eſtimated.

ROckets are eſtimated either by Meaſure or by Weight; if by Meaſure, then by the Common Standard by Inches or by Feet; if by Weight, then they are eſtimated by Caſt Iron, that is, by the Gunners Rule, *viz.* An Inch Rocket weigheth two Ounces and a quater: an Inch and half Rocket weigheth half a Pound: a two Inch Rocket weigheth a little above a Pound: a three Inch Rocket weigheth almoſt four Pounds: a four Inch Rocket weigheth nine Pounds: an eight Inch Rocket weigheth ſeventy two Pounds, which may be called a Rocket Royal.

PROPOSITION XIII.

Of the cauſe of the Rockets riſing.



LET ACB be the hollow Cone for the the Fire, A y C Z B the Superficies of that Cone, all the Lines O Z at right Angles with B C, and all the Lines O y at Right Angle with A C; now all the Angles Z O y being towards R, whether the Angles Z O y are Obtuſe or Acute, but the more acuter the better. The Rays of fire Z O and y O iſſuing from the ſides of the Cone B C and A C, and continually agitating with greater force one upon another at O, forcing the whole Cone B C A upward from the point R; (and the wider the bore is (in Reaſon) the Rocket will riſe with the greater velocity; if the Compoſition and deepneſs of boring be ſutable.) By the Rays Z X, and

and y Z of fire, croſſing each other at the Center of the Cone R, and the point R, as it were, remains fixt; and here the ſimilitude of Guns and Rockets appears plainly, a Gun remains fixt upon the Center of Motion of the Trunnions, and projects its burden forth; but a Rocket flys from its burden, leaving it at R, as it were fixt.

PART II.

TO OUR PYROBOLISTES.

A duplicate Propoſition.

HAving one Rocket well proved in all its Parts, *viz.* a three Inch Rocket. Then,

To decreaſe the Velocity of the Compoſition of the aforeſaid Rocket, to make it fit for a 4 Inch 4 ½ and 5 Inch Rocket.

And to increaſe the Velocity of the aforeſaid Compoſition, to adapt it to a 2 Inch 1 ½ and 1 Inch Rocket, keeping the ſame kind of Boring.

Secondly, From the expoſed Rocket of 3 Inches, to increaſe the Diameter of the Orifice of the Rockets of 4 : 4 ½ and 5

Inches Diameter; and to decreaſe the Diameter of the Orifice of the Rockets of 2: 1 ½ and 1 Inch Diameter, to adapt them to the expoſed Rocket, keeping the Compoſition of the ſame Velocity.

From Experimental and Mathematical Demonſtration.

The Reſolution of this Problem will manifeſtly ſhew, the invalidity of the Doctrine of Shooting by the increaſe and decreaſe of Powder; and that weak and narrow Scantling it pinfolds in, *too mean for this lofty Engine.* It alſo tells the Gun-Founder how to give his Guns their due Fortification; otherwiſe they may become uſeleſs Inſtruments of War. It teacheth our *Pyroboliſtes* to direct their Work ſo that it may riſe well, and not break nor fall. It teacheth Artificers to increaſe and decreaſe the force or ſtrength of their Materials in any poſſible Proportion aſſigned.

This Propoſition was publickly propoſed three Months before the publication of this Book, but no Reſolution given by any.

PRO-

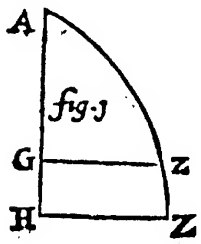
PROPOSITION XIV.

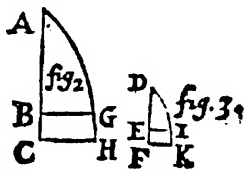
The Complication of Rockets in Relation to their Borers.

FRom a 2 Inch and half Rocket, we Complicate other Rockets, *viz.* a four Inch Rocket thus, we take the Cube of 4, which is 64, alſo we take the Cube of 2 ½, which is 15.625, with which we divide 64, the Quotient is 4; and ſo many times the leſſer Rocket is contained in the greater, that is as 4 is to 1. Then I look into the Tables of Ranges for the year 1691. *June* 1, and in the ſecond Column I find the requiſite of Powder 1 and 4, and againſt the 4 in the third Column I find the Range 3377; and in the third Column againſt 1 I find the Range 652, which I multiply by 4, the Ratio of the Rockets, and it is 2608: Now if this laſt Number had been equal to 3377, the Range with the Quadruple of Powder, it would have confirmed the ſhooting by the increaſe and decreaſe of

 Powder;

Powder; but as it is ſhort, it is a viſible Demonſtration of the error of that Doctrine: and if the Doctrine of ſhooting by the increaſe and decreaſe of Powder were true, there would be no need for our Pyroboliſtes to give different Velocities of Compoſitions to different ſizes of Rockets, but one Compoſition would have ſerved all ſizes; which every Youth knows the Contrary.





In the Parabola A H Z let A G be 2608, and A H 3377; then G Z and H Z are the Velocities of the equal and unequal Ranges. *Toricellius* 22. *Prop. de motu projec. lib ſecund.*

Then as G Z the Velocity of the equal Range; is to one third of the Diameter of the four Inch Rocket 1.333; ſo is H Z the Velocity of the unequal Range,

Range, to a larger Diameter of the 4 Inch Rocket, to keep the ſame Compoſition.

Or as the equal Range 2608, is to the unequal Range 3377; ſo is the ſquare of the Diameter of the Orifice of the 4 Inch Rocket, to the ſquare of the Diameter of the Orifice of the Rocket inlarged, keeping the ſame Compoſition.

Or as the equal Range 2608, is to the unequal Range 3377; ſo is the Area of the Orifice of the Rocket of 4 Diameter, when taking $\frac{1}{3}$ of the Diameter; to the Area of the Orifice of the ſame Rocket when enlarged, to bare the Compoſition that would ſerve a Rocket of two Inches and a half, taking $\frac{1}{3}$ of the Diameter of the Rocket for the Diameter of its Orifice.

Example.

2608	The equal Range	3.416308
3377	The unequal Range	3.528531
	The ſquare of 1.333, &c. the Diam. of the equal Orifice	.249660
	Take the half	.361883
	The Diam. of the new Orifice 1.516 one Inch and half	.189941

Take

Take another Example.

Auguſt 24. 1691. I look in Column 2, and find the Requiſites of Powder half an Ounce, and 2 Ounces, and againſt thoſe Requiſites in Column 3 I find 1482 the unequal Range, and 236 the equal Range; which I multiply by 4, and it makes 944.

944 The equal Range	2.974972
1482 The unequal Range	3.170848
The Square of 1.333, &c. the equal Orifice	.249660
	.445536
The Diameter of the new Orifice 1.67	.222768

Here may be ſeen the concurrence of Experiments made upon another account, not then thinking to apply it to the Complication of Rockets. I made 2 Rockets of 4 Inches Diameter, and a Taper bit according to this method, and bored three Diameters, and left 2 Inches Solid, and they roſe well.

An example of a Rocket of 6 Inches Diameter, keeping the ſame Compoſition. Take the Cube of 6, which is 216, divide

divide that Cube by the Cube of 4, which is 64, the Quotient is 3, that is the Compoſition in the Rocket of 4 Inches, is to the Compoſition in the Rocket of 6 Inches, is as 1 to 3; then I look in the Table of *Aug.* 24. and find in the ſecond Column the Requiſites of Powder half an Ounce, and an Ounce and a half; and againſt theſe Requiſites in Column three 800, the unequal Range, and 236 the equal Range, which I multiply by 3, and it makes 708: then as 4 is to 6, ſo is twelve half quarters of an Inch, the Diameter of the new Orifice of the four Inch Rocket, to eighteen half quarters of Inches; that is 2 Inches and 1 quarter: or as 4 is to 6, ſo is 1 $\frac{1}{2}$, that is 3 halfs, to 4 $\frac{1}{2}$ half Inches, that is 2 $\frac{1}{4}$. Then I had no ſuch Ranges, that their Requiſites of Powder were in Proportion as the Cube of 6 is to the Cube of 2 $\frac{1}{2}$; therefore was I forced to help my ſelf by Proportion, which is the ſame in Subſtance.

708 The equal Range	2.850033
800 The unequal Range	2.903089
The Square of 2 $\frac{1}{4}$, or 18 half quarters	2.510544
The half of this Logarithm	2.563600
Half quarters of Inches 19.13 that is 2.3 is	1.281800

A ſecond Example, April 21. 1692.

I look in Column 2, and find the Requiſites of Powder 12 Drams, and 36 Drams; and againſt theſe Requiſites in the third Column I find 1176 the unequal Range, and 303 the equal Range, which I multiply by 3, and it makes 909.

909 The equal Range	2.958564
1176 The unequal Range	3.070407
The Square of 18 half quarters	2.510544
	2.622387
20.47, that is 2 Inches and a half, and $\frac{47}{100}$	1.311193

Here may be ſeen one Example makes the Diameter a little more than two Inches and a half, and in the other a little leſs, therefore we make the Taper Bores juſt two Inches and a half for a 6 Inch Rocket. To work from a two Inch and a half Rocket to an Inch, put the unequal Range in the firſt place, and the Work is done. The Compoſition theſe 4 and 6 Inch Rockets were made of, were 1 Sulphur, 1 $\frac{1}{2}$ Coal, and 4 Saltpetre; but I believe 1 Sulphur, 1 Coal, and 4 Saltpetre would do better, there being no great

great danger of the Rocket breaking, by Reaſon of the large Diameter of the Bore, and Tapering to a point; and by the ſame Reaſon, a leſſer ſolid Head is required, that is about 2 Inches in a 4 Inch, and 1 $\frac{1}{4}$ in a 6 or 8 Inch Rocket, will ſuffice.

PROPOSITION XV.

The Complication of Rockets in Relation to their Compoſition, with ſome Cautions and Limitations.

TO decreaſe the Velocity of the Compoſition of 1, 1 $\frac{1}{2}$, and 4, which ſerved to a 2 $\frac{1}{2}$ Inch Rocket, to make it fit for a 4 Inch Rocket: remember the Ratio of the Rockets are as 1 to 4. Look in the Table of Ranges, and find the Requiſites of Powder in the ſecond Column, as 1 to 4, and againſt them in the third Column the Ranges, *viz.* 3377 and 652, then multiply the equal Range by 4, and it is 2608, (in fig. 1.) In the Parabola Z A H, let A H be equal to 3377, and A G equal to 2608; then H Z, and G Z will be the

the Velocity of the Powder, which projected thoſe Ranges, and we increaſe or decreaſe the Velocity of the Salpetre by the Ratio of G Z to H Z: then let A C in fig. 2, be equal to H Z in fig. 1, and A B in fig. 2, be equal to G Z in fig. 1; then draw the Ordinate C H and B G in fig. 2, and by theſe two Lines, *viz.* C H and B G we increaſe or decreaſe the Velocity of the Coal. Further, let D F in fig. 3, be equal to C H in fig. 2; and D E in fig. 3. be equal to B G in fig. 2: draw the Ordinates F K and E I, and by theſe 2 Lines we increaſe or decreaſe the Velocity of the Sulphur.

Then if we take the Logarithm of

(0)	(1)	(2)	(4)	(8)
3377	3.518531	1.759265	0.879632	0.439816

And is

2608	3.416308	1.708154	0.854077	0.427038

that is, the Ranges under (0), their Logarithm under (1) the half of the Log. under (2), the numbers anſwering thoſe Logarithms are the Lines H Z and G Z in fig. 1. The Logarithm under (4) is the fourth part of the Logarithm under (1): The Numbers anſwering theſe Logarithms, are the Lines C H, and B G in fig. 2.

fig. 2. Further, the Logarithm under (8) is the eighth part of the Logarithm under (1); the Numbers anſwering thoſe Logarithms, are the Ordinates F K and E I in the Parabola F D K.

Or you may take the difference of the Logarithms under (1) } 102223 *viz.*

Half	51111
Quarter	25555
Eighth	12777

By Adding or Subtracting theſe Log. to or from the Logarithm of the Saltpetre, Coal, and Sulphur, you have your deſire, *viz.* their Velocities either increaſed or decreaſed: or thus, take the difference of the Logarithm of the two Ranges 102223, and Subtract it from the Logarithm of the Square of the Number of Drams, Ounces, or Pounds of Saltpetre, or from the Logarithm of the fourth power of the Numbers of Drams, Ounces, or Pounds of Coal. And Laſtly, that difference being Subtracted from the Logarithms of the eighth power of the Number of the Drams, Ounces, or Pounds of Sulphur, there will remain three Logarithms, the firſt being divided by 2, the ſecond

second by 4, and the third by 8; there will remain three Logarithms, the Numbers answering to which, will be the Number of Drams, and Tenths of the Saltpetre, Coal, and Sulphur desired.

To Weaken the Velocity of the Composition of 1, 1 ½, and 4.

3377 The unequal Range	3.518531
2608 The equal Range	3.416308
The Square of 64 Drams of Saltpetre	3.612360
Take the half	3.510137
Drams 56.9 nine Tenths of Saltpetre	1.755068

The fourth power of twenty four Drams of Coal	5.520844
The difference of the Logarithm of unequal, and equal Ranges Subtract	.102223
Is the Logarithm of the fourth power, which being divided by fourth	5.418621
22 Drams $\frac{43}{100}$ of Coal	1.354655

The

The eighth power of fifteen Drams of Sulphur	9.632960
The difference of the Logarithm Subtract	.102223
Is the Logarithm of the eighth power which being divided by 8	9.530737
15 Drams $\frac{64}{100}$ of Sulphur	1.191342

The Composition will be Sulphur 15 ½, Coal 22 ½, and Saltpetre 57; but if you quicken the Velocity, the equal Range will be in the first place of the Proportion.

PROPOSITION XVI.

Tables of Ranges made with Mortar-pieces.

June 1. 1691. On *Wimbleton-Heath* at 15 *deg.* of Elevation, with a four Inch Mortar-piece, and a turned Iron Ball.

1	2	3
Experiments.	Powder.	Chain.
1	½	213
2	1	652
3	2	1640
4	4	3377

August.

August 24. 1691: At 15 *deg.* of Elevation, with a 3 ½ Inches Mortar-piece, and a turn'd Iron Ball.

1	2	3	4	5
	The Chamber of this Mortar-piece a Frustum of a Cone.		The Chamber of this Mortar piece a Frustum of a Sphere.	
	Powder	Chain.	Powder	Chain.
1	½	236	½	144
2	1	496	1	304
3	1 ½	800	1 ½	1258
4	2	1482	2	3394

April 21. 1692. At 15 *deg.* of Elevation, with a 3 ½ Inch Mortar-piece, and a turn'd Iron Ball.

1	2	3
Experiment.	Powder.	Chain.
1	12	303
2	24	746
3	36	1176
4	48	1820
5	60	2698

Thus have I given plain and eaſie Rules to the Young Pyroboliſtes for the making of ſmall Rockets; and alſo for the making of great Rockets, to them of a greater Knowledge and Purſe, even ſuch as was reputed impoſſible; for a 4 Inch Rocket was given in by our ableſt Pyroboliſtes to be out of ſize, and therefore impoſſible to riſe. Now, if that 4 Inch Rocket was thought ſo, what will they ſay to them of 6, 8, 10 or 12 Inches Diameter; for certainly this Rule takes in all ſizes to 500 or 1000 weight, or higher.

Neceſſa-

Inches and half Inches.	Pounds of Rockets.	Ounces	Ounces of Compoſ. for Rockets.	Pounds of the Mall.	Ounces
1	2	3	4	5	6
1		02	0.01		12
1½		08	0004	0002	08
2	001	02	0010	0006	05
2½	002	04	0018	0011	11
3	003	12	0032	0020	01
3½	006	00	0051	0032	04
4	009	00	0076	0048	00
4½	012	13	0108	0068	08
5	017	09	0148	0093	12
5½	023	06	0197	0120	12
6	030	06	0256	0162	00
6½	038	10	0326	0206	06
7	048	04	0407	0251	00
7½	059	05	0500	0316	06
8	072	00	0607	0384	00
8½	086	06	0728	0460	09
9	102	08	0864	0546	12
9½	120	09	1016	0643	00
10	140	10	1285	0748	04
10½	162	13	1372	0868	03
11	187	02	1578	0998	04
11½	213	14	1805	1140	10
12	423	00	2048	1296	00

The Uſe of theſe Neceſſary Tables.

IN the firſt Column you have the Inches and half Inches, to 12 Inches. In the ſecond and third Columns you have the weight of Pounds and Ounces of the Rockets, when ſix Diameters in length. In the fourth Column you have the Ounces of Compoſition to fill thoſe Rockets 4 Diameters. In the fifth and ſixth Columns you have the weight of the Mallets to drive thoſe Rockets in Pounds and Ounces.

An Example in the whole, for a three Inch Rocket. I find 3 in the firſt Column under Inches and half Inches; in the ſecond and third Column, under Pounds and Ounces of Rockets, I find three Pounds and 12 Ounces the weight of the Rocket when finiſhed, being 6 Diameters. In the fourth Column I find 32 Ounces of Compoſition to fill 4 Diameters. In the fifth and ſixth Columns I find 20 Pounds 4 Ounces for the Mallet to drive that Rocket.

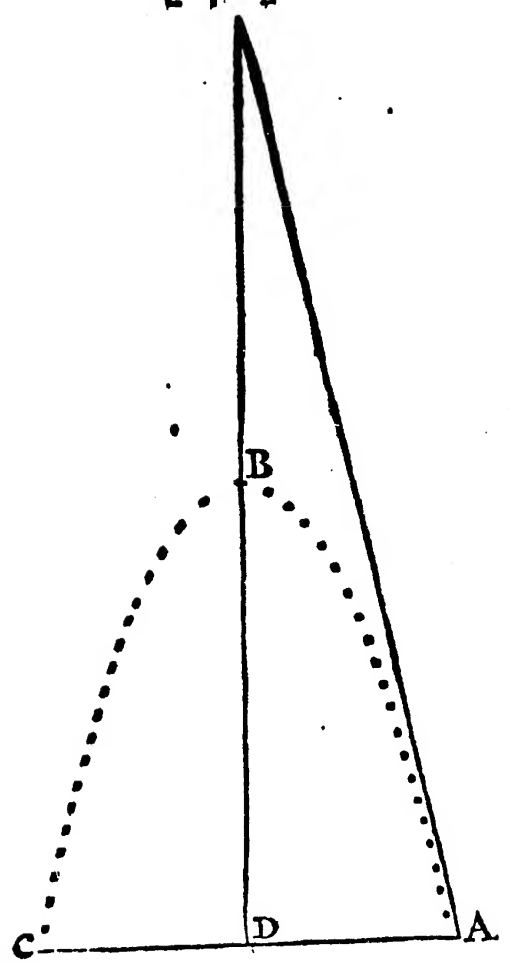
When Rockets are of a great weight, the Mallet will be too heavy to manage, therefore do thus. The Mallet of a three Inch Rocket, *viz*, 20 Pounds weight is of

of a good ſize; and we will make an Example of a 3 Inch and 7 ½ Rockets, and we will take it as uſeful that all Rockets to 3 Inches Diameter, may be filled with eight Charges, but further not, then againſt 7 ½ in the firſt Column. In Column 4 I find 500 Ounces of Compoſition for that Rocket, which I divide by 8, and the Quotient will be 62.5. In the Parabola A H Z, let A H be the Number of Ounces 50625 in the Mallet for the 7 ½ Rocket, and A G the Number of Ounces 324 in the Mallet for a 3 Inch Rocket; then the Ordinates H Z and G Z will be the Forces of thoſe Mallets; then as H Z is to G Z, ſo is 62.5 to 15.811, that is 15 Ounces and $\frac{811}{1000}$ ſhall be your Charge of Compoſition. Further, divide 62.5 by 15.811, the Quotient will be $3.\frac{2212}{15000}$ the Number of Charges in the eight part of the Compoſition; then multiply 39529 by 8, there will be $31.\frac{223}{1000}$ Charges in that Rocket. Laſtly, give about eighteen blows to every Charge, with that Mallet for the 3 Inch Rocket, ſo your Work will be done, by two Men, in two hours.

324	2.510545
62.5 Squared	3.591760
5062.5 Sub.	6.102305
	3.704364
2	2.397941
15.811 is Sub.	1.198970
62.5 is from	1.795880
3.9529 Reſt	0.596910
8. Log.	0.903090
31.623 Sum of 2 Logarithm	1.500000
15811 Add	1.198970
500. the Sum of Logarithm	2.698970

June 26. 1696. Then was fired a 4 and 6 Inch Rocket, Mr. *Ayres* Junior fired them both off a hand, Mr. *Dandridge*, Mr. *Rodway*, my ſelf, and ſeveral other being preſent: the 6 Inch Rocket had 3 Inches ſolid Head, that is about the double of what it ought to have had, the Reaſon of that was to hold Fire; it moved off the Nails at about 78 *deg.* of Elevation, and the Horizontal Range was juſt 15 Chains, that is 330 Yards, by which we may find the Altitude of that Parabola it moved in, and the greateſt Range, and Conſequently the greateſt Perpendicular Altitude it could have reached.

In



In the Parabola A B C, Let A C be equal to 330 Yards, A D equal to 165 the Angle D A E 78 degrees, then in the right Angled Triangle E D A.

Radius

Radius	90	10.000000
Tangent	78	10.672525
A D	165	2.217484
D E	776.22	2.889989
D B	388.11	
As the Sine of the double of the Elevation	407	2.609594
Is to Radius	1000	3.000000
So is the Horizontal distance at 78 *deg.*	330	2.518514
To the greateſt Range in the Parabola	8108	2.908920
Half of the greateſt Range is the Perpend. hight deſired	405.4	

So then the greateſt height of that 6 Inches Rocket in its flight was three hundred eighty and eight Yards, had it been put Perpendicular, its height would have been four hundred and five Yards.

The flight of Rockets does ſufficiently well agree with that of the Parabola at each end of the Quadrant; but towards 45 degrees it differs more.

A Rocket of an Inch and half Diameter, filled 5 Diameters, and bored two and a half, and a little more, with this Compoſition, *viz.* 8 Powder-duſt, 6 Saltpetre, 2 ½ Coal, and 1 Sulphur, and layed to 30 degrees of Elevation; Ranged the Rocket 880 Yards, that is half a Mile.

To

To make Rockets to Swim upon the Water, Dive into the Water, and keep above the Water.

An Example of an Inch Rocket.

MAke the Caſe 12 Diameters, which will be in this Example 12 Inches, fill it with two Compoſitions, *viz.* a Weaker and a Stronger; fill 2 Inches with the Weaker Compoſition, then 1 ½ with the Strong, then 2 with the Weak, 1 ½ with the Strong. Laſtly, 2 Inches with the Weak, then there will remain 3 Inches for Corn Powder, for the Report.

The Weak Compoſition to Swim above Water; take 3 of meal Powder, 1 of Coal.

The Strong Compoſition to Dive under the Water, and leap above the Water; take 8 of mealed Powder, 1 of Saltpetre, and 1 of Coal.

To

To divide the Driver.

FRom the lower end of your Driver ſet off 3 Inches, then 2 Inches, then 1 ½, then 2 Inches, then 1 ½. Laſtly, 2 Inches; make the Rockets of a juſt length, and ſo you may ſee the Diviſions of the Driver appear above the Caſe as you fill.

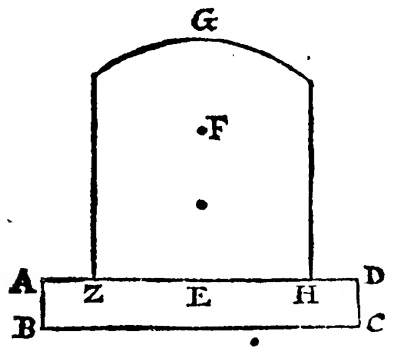
The Uſe.

FIre the Rocket in your Hand with with your Port-fire, through it into a deep Water, (otherwiſe it will ſtick in the Mud) it will Swim a little while; but when the Strong Compoſition takes fire it will Dive, and when the Strong Compoſition is ſpent it will jump up, *&c.* The Weak Compoſition being the laſt, the Rocket for ſome time will Swim upon the Water, and then give a Report. This Rocket is all Solid.

To make a Rocket Charger.

LET the length of the Charger E G, be one Diameter and half, the breadth of the Charger H Z, one Diameter and one third, the length of the Neck

Neck of the Charger that ſlippeth upon the Handle B C, two Diameters; the breadth of that Ferril A B, one third of the Diameter of the Rocket: betwixt eight or nine of theſe Charges will fill a Rocket 4 Diameters.



You may cut the Charger A B C D H G Z A in Paper, then it may be made in Copper, Cloſe A to D, and B to C, Sodder both ends together; bring H G Z into more than half a round, and A B and C D in a round, put it then upon a Handle, then it is fit for uſe.

To

To make good Coal for Rockets.

TAke pieces of a light dry Deal Board about 12 Inches in length, and about the thickneſs of 2 Fingers or leſs; put them into an Oven, put fire to the Wood; when they are burned enough take them out, and put them into an Iron, Braſs, or Eathern Pot, cloſe it well with a Cover, that it takes no Air, the Fire being extinguiſhed, beat it and paſs it through a fine Sieve, then it is fit for uſe. If the Wood be not well burnt, put it into the Oven again, and ſo repeat your Work: ſuch Coal will make a Rocket fly very lively, if not with two much Life.

Compoſitions for Reports.

	A	B	C	D
li Saltpetre	9.	4.	3.	2.
Salt of Tartar	3.	3.	2.	1.
Sulphur	1.	2.	1.	1.

Take Sulphur 1, Tartar 3, and Saltpetre 9, grind theſe well together, and dry them. A few Grains of this Powder being fired, will give as great a Clap as a Musket when it is diſcharged. Dr. *French, pag.* 171. Take any of theſe Ingredients under

under A B C or D, mix them well together, put a little quantity of that mixture into a Fire-Pan, ſet it upon the Fire, and in a little time it will give a great Report.

A further uſe of the Tables.

WHat is done in the 14 and 15 Propoſitions, by taking the Cubes of the Diameter of the Bores of the Rockets, may be done by the Tables in 2 and 3, or Tab 4. Thus, look in the firſt Column for the Diameters of the Rockets, *viz.* 2 and 4, and againſt them, in Column 2 and 3, I find 2 Pounds and 4 Ounces, and 9 Pounds, divide the greater Number by the leſſer, the Quotient will be 4, near enough, ſo the Ratio of theſe two Rockets are as 4 to 1, and this is by the weight of the Rockets.

In the other Example I find 4 and 6 in the firſt Column, and againſt them in Column 4, I find 76 and 256 Ounces of Compoſition for theſe two Rockets; then divide the greater by the leſſer, the Quotient will be 3 and more, which is the ſame thing as if you made uſe of the Cubes of their Diameters; for indeed theſe Tables are made by the Cubes of the reſpective Diameters.

A

A Concluſion.

IF any one preſumes to ſay they have Reſolved the 14. Propoſition before the Publication of this, they might have been ſo kind as to put it into Practice for the Defence of the Nation. If any ſay they can do it, I deſire them ſo to do, *That I may ſee my deſires accompliſhed*, viz. Great Guns and their Carriages truly fortified and neatly made, *which would be great ſatisfaction*; however this may ſhew to the next Age what has been offered to this.

July 25.
1696.

F I N I S.